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The value of instability: An investigation of intra-subject variability in brain activity among obese adolescent girls

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Abstract

BACKGROUND—The present study investigated the value of intra-subject variability (ISV) as a metric for revealing differences in cognition and brain activation associated with an obese versus lean body mass.

METHODS—Ninety-six adolescents with a lean body mass (BMI %-ile = 5–85), and 92 adolescents with an obese body mass (BMI %-ile ≥ 95), performed two tasks (Stroop and Go/NoGo) challenging response inhibition skills. The standard deviations and averages of their reaction time and P300 electroencephalographic responses to task stimuli were computed across trials.

RESULTS—During the Go/NoGo task, the reaction times of subjects with an obese body mass were more variable than those of their lean body mass peers. Accompanying the greater ISV in reaction times was a group difference in P300 amplitude ISV in the opposite direction across both tasks. The effect sizes associated with these group differences in ISV were marginally greater than the effect sizes for the comparisons of the group means.

CONCLUSIONS—ISV may be superior to the mean as a tool for differentiating groups without significant cognitive impairment. The co-occurrence of reduced ISV in P300 amplitude and elevated ISV in reaction time may indicate a constraint among obese adolescent girls in the range of information processing strategies and neural networks that can compete to optimize response output. It remains to be determined if this decrement in neural plasticity has implications for their problem solving skills as well as their response to weight management interventions.

Keywords

obesity; response inhibition; event related potential; P300; intraindividual variability; adolescent

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

INTRODUCTION

Many studies have compared the cognitive abilities of obese and normal weight adolescents^{1, 2}. Yet, the magnitudes of the observed differences have been small. Accordingly, questions have been raised about the importance of the differences and their role in behaviors that promote weight gain. The goal of the present study was to address this limitation by identifying an alternative means of comparing obese and normal weight adolescents in their cognitive abilities. It was expected that this alternative measurement method would yield findings that are more conceptually and statistically compelling than we see in the extant literature.

The alternative method borrows ideas from two approaches. The first approach follows the tradition of cognitive psychology. In a typical study in this tradition, obese and lean adolescents are asked to perform multiple trials of a cognitive task. Their variability in performance over the trials is ignored. Instead, the emphasis is on comparing the groups on the predominant or average level. Using this approach, researchers have identified statistically significant group differences in response speed or accuracy on tasks measuring motor coordination³, complex working memory^{4, 5}, selective attention⁶⁻⁹, and response inhibition¹⁰⁻¹² skills.

The second approach follows the traditions of personality and clinical research. It does not involve a challenge to cognitive abilities *per se*. Instead, it uses questionnaires or interviews to measure cognitive style. The literature associated with this approach highlights impulsivity as a problem^{12, 13} affecting obese adolescents. It also discusses the overlap of obesity with psychiatric disorders, such as Attention-Deficit Hyperactivity Disorder¹⁴⁻¹⁷, Conduct Disorder^{18, 19}, and Binge Eating Disorder^{20, 21}, wherein occasional dysregulation of behavior is a prominent feature. Implicit in this literature is the idea that obese adolescents are not consistently impaired. The impairment fluctuates and may not be detectable at all times.

The alternative method integrates these traditional approaches by measuring the variability in performance during each task. In this manner, the present study captures the instability in behavior suggested in the personality and clinical literatures in the specific cognitive domains of interest in the cognitive psychology literature. The present study also obtained information about intra-subject variability (ISV) in brain activity during each task.

Experts in cognitive psychology may recognize that ISV in task performance has rarely²²⁻²⁴ been considered in studies of pediatric obesity and many other disorders correlated with brain function. Researchers studying healthy brain maturation or Attention Deficit/Hyperactivity Disorder (ADHD) have better appreciated its value as a metric for differentiating individuals and groups. In those topic areas, comprehensive reviews, including a thoughtful treatise by MacDonald and colleagues²⁵, remind us that ISV is often as stable a characteristic of subjects as the mean value. Indeed, the test-retest reliability coefficients for a popular index of it -- the standard deviation of reaction time (SDRT) -- are in the vicinity of 0.7-0.8^{26, 27}. To some readers, a reliability estimate of this magnitude may be a surprise for it shows that ISV is not simply noise or measurement error. It obviously

contains a sizeable component that is systematic. The component may be powerfully related to learning, fatigue, characteristics of the task, and characteristics of the subject.

It may likewise be surprising to discover that there are neural contributors to ISV. The contributors have been revealed with the same methods that have been used for detecting neural correlates of mean reaction time. Some studies have tested the association of SDRT with brain structure. Other studies have examined the association of SDRT with ISV in brain activity.

For example, in a study of the former type, Tamnes and colleagues²⁸ recruited 92 healthy children and concurrently examined SDRT and several measures of white matter integrity: fractional anisotropy and mean, axial, and radial diffusivity. Using partial correlations adjusting for age and mean reaction time, they found that SDRT was negatively correlated with fractional anisotropy and positively correlated with diffusivity across most conditions of a response inhibition task. It is noteworthy that mean reaction time was not similarly correlated with poor white matter integrity. Thus, this index of ISV in reaction time did offer greater power than the mean in a sample of healthy adolescents.

To our knowledge, studies of the association between SDRT and ISV in brain activation have only used event related electroencephalographic potential (ERP) methods. Functional magnetic resonance imaging (fMRI) studies have not examined the association on a trial-by-trial basis. Indeed, in this regard, fMRI studies are at a disadvantage. The poor temporal resolution and slow recovery of the BOLD response is a problem when the interest is in changes from moment-to-moment or trial-to-trial. Diffusion or cross-contamination can occur. In addition, it is arguable whether the fMRI response is sufficiently large and reliable^{29–32} for single trial analysis.

The extant ERP studies of ISV have focused on healthy volunteers in whom variability may be capped or truncated. For example, Adamo and colleagues³³ examined SDRT and P300 amplitude ISV in healthy adults performing a flanker/No-Go task. They detected no significant correlation between SDRT and the standard deviation of the P300 response to the “Go” stimulus. The task design did not allow them to examine SDRT during the more difficult “No-Go” condition, wherein variability would not be as restricted³⁴.

More compelling evidence of an association between SDRT and P300 amplitude variability was reported by McIntosh and colleagues³⁵. They examined small groups of 8–15 year old children and 20–33 year old young adults. The study compared the two age cohorts in a cross-sectional test of the effect of brain maturation. The authors reported an increase in P300 amplitude ISV and a decrease in SDRT with age. Their finding is consistent with theories from the priming literature and elsewhere³⁶ suggesting that the healthy or mature brain response to a task involves the co-activation of multiple neural networks and information processing strategies that compete to optimize response output. The measurable manifestations of this process are an increase in the ISV of P300 and a decrease in SDRT.

In the present study comparing groups of adolescents differing in body mass, we expected a pattern of results that is consistent with findings from the brain maturation literature: greater

variability in P300 amplitude and less variability in reaction time in the healthy, lean body mass group versus the obese group.

MATERIALS AND METHODS

Subjects

Female adolescents, aged 14–18 years, were recruited with posters, direct mail solicitations, and newspaper advertisements for a larger project examining genetic, psychological, and neurophysiological markers of obesity risk. The advertisements mentioned weight management problems, risk-taking tendencies, conduct problems, or a family history of risk-taking or drug/alcohol abuse as potential qualifiers. Each interested volunteer and one of her biological parents were asked to call a research assistant for additional information and eligibility screening. Volunteers who reported no past or current pregnancy, psychosis, a recent history of regular substance use, or major medical disorders that would complicate body weight (e.g., HIV, thyroid disease) or electroencephalographic responses (i.e., seizure disorder, heart disease, hearing loss, uncorrected visual impairment) during the telephone and in-person interviews were deemed eligible and became subjects in the protocol. They were paid for their time and effort.

Procedures

Informed consent and medical release documents approved by the university's Institutional Review Board were reviewed and signed by the subject and parent on the day of data collection. On the same day, the parent completed a questionnaire reviewing the subject's health history as well as a separate questionnaire that inquired about obesity, alcohol/drug dependence, and hypertension among first and second degree relatives. The parent was then dismissed and asked to return at the conclusion of the session to retrieve his/her daughter.

The adolescent subject was escorted to a private office where she completed several rating scales assessing psychological constructs with documented relevance to overeating or obesity. These measures of impulsivity or inattention were the Barratt Impulsiveness Scale (BIS)³⁷, Toronto Alexithymia Scale (TAS)^{38, 39}, Borderline Symptom List (BSL)⁴⁰, and the Inventory of Callous/Unemotional Traits (ICU)⁴¹. Other questionnaires and interviews were administered for the purpose of describing the general background characteristics of the sample. The additional background assessments included a modified Drug Abuse Screening Test (DAST)⁴², the computerized Diagnostic Interview Scale for DSMIV⁴³, and the 90-day Timeline Follow-back Interview for alcohol and drugs⁴⁴. Findings from the DSMIV and Timeline Followback Interviews were unremarkable and rarely triggered the exclusion of a volunteer. The interview data are therefore not reported here but are available on request.

A battery of objective tests was also administered. The battery included a measurement of the subject's height and weight with a Health-o-meterTM (McCook, IL) stadiometer. Height and weight data were later converted to Body Mass Index Percentile (BMIP) using the growth charts published by the U.S. Centers for Disease Control. To provide a second measure of adiposity less sensitive to muscularity, skinfold thickness was measured over the right and left triceps with calipers (Lange calipers, QuickMedical, Issaquah, WA). Two

female technicians involved in skinfold thickness measurement were trained in the use of the calipers prior to study initiation. During the training period, their goal was to achieve an inter-rater reliability (intraclass correlation coefficient) greater than 0.85 within a block of 50 measurements. The maintenance of measurement reliability was checked at 3-month intervals. If needed, additional training was undertaken to return to the criterion level of reliability.

Also, an objective test to exclude recent cigarette use was performed with a breath carbon monoxide monitor. In addition, two saliva samples were collected. The first sample was used as a screen for excluding subjects who recently used illicit drugs. The second sample was preserved for DNA extraction and genetic analyses to be performed at a later time.

The subject was then escorted into a sound-shielded chamber and seated in a comfortable chair facing a 14-inch computer monitor and a panel with two response keys. In the chamber, she was fitted with an electrode cap containing 64 Ag/AgCl EEG electrodes arranged in a conventional montage. Reference electrodes were taped to her earlobes. A ground electrode was applied to the middle of her forehead. Electrode sites were abraded and connected to the electrodes with conductive gel. Interelectrode impedances were checked and maintained below 5 Kilohms.

After the electrodes were applied, the subject received instructions about the tasks she would perform during the ensuing 70-minute battery. Generally, the instructions emphasized the importance of accuracy over speed in performance. However, speed and constant alertness to the tasks were also emphasized. Excessive movement and inattention were discouraged. Despite the instructions, a small number (<10) of subjects were non-compliant. They were dismissed. Their data were not retained for analysis.

For this analysis, we chose two cognitive tasks that have often served as experimental paradigms in the study of response control: a Go/No-Go task similar to the Continuous Performance Test⁴⁵ and the Stroop Task⁴⁶. Two considerations influenced this choice. The first consideration was the difficulty level of the tasks. We wanted to ensure that the tasks were sufficiently difficult to elicit significant ISV in performance. The second consideration was the relevance of the underlying skill to the etiology and maintenance of obesity: poor response control is related to a diminished ability to delay rewards⁴⁷, a preference for high-calorie take-out foods⁴⁸, and poor obesity treatment outcome⁴⁹. We chose two tasks over a single task because it provided an opportunity to determine if ISV in brain activity was a reproducible characteristic across tasks in the same individual.

The Go/No-Go Task⁴⁵ was comprised of 200 presentations of a frequent stimulus, the numeral “1”, requiring a button press. It was intermingled with 50 presentations of a rare stimulus, the numeral “0”, requiring inhibition of the prepotent button press response. The stimuli subtended a visual angle of 2.86 degrees and were presented for 200 ms each. They were presented in a white font every 1.3 seconds.

The Stroop Task was also composed of discrete trials. Three-hundred visual stimuli, i.e. the words ‘RED’, ‘BLUE’ or ‘TOWN’, were presented equiprobably in a red or blue font on a dark background. The stimuli were delivered at a rate of 1 stimulus every 2.3 s for 200 ms

each. The subject was asked to indicate the color of the font by pressing 1 of 2 response keys, labeled 'red' and 'blue', within a response deadline of 1500 ms. She was instructed to ignore the word. The task therefore yielded three major trial types: a neutral word, "TOWN" (#1), printed in different font colors, as well as the color names "BLUE" and "RED" printed in either a compatible (#2) or incompatible (#3) color. The third trial type is the classic Stroop stimulus. It delays responses and produces errors because the color name and its font color evoke competing responses which must be distilled to a single response to the font color.

Data Processing

During the Go/No-Go and Stroop tasks, electroencephalographic and eye movement signals were appropriately amplified (gain=10K). Along with markers indicating stimulus and response onsets, the signals were routed to an A/D converter, digitized at a rate of 500 Hz, and processed through a zero-phase shift filter (high pass=0.5 Hz, 12 db/octave roll-off; low pass=6 Hz, 48 db/octave roll-off). Epochs of EEG surrounding the onset of the stimuli were then extracted. The epochs spanned 100 msec preceding to 700 msec following onset.

During other off-line computations, a linear regression algorithm⁵⁰ implemented in Scan version 4.3 software (Compumedics/Neuroscan, Inc) mathematically removed eye movement and eye blink artifacts from each epoch. Eye-movement and baseline-corrected epochs were then screened to eliminate those with a voltage deviation <-50 or >+50 microvolts or with an incorrect button press response.

Summary measures of P300 activity were computed at frontal (Fz), central (Cz), and parietal (Pz) midline electrode sites. Mean P300 amplitude was calculated as the average voltage, relative to the prestimulus baseline, over a post-stimulus epoch of 250–600 msec (Figure 1). The standard deviation of P300 was calculated as the average of standard deviation measurements over the same post-stimulus epoch. These measures were calculated in the ERP elicited by the rare, "No-Go" stimuli during the Go/No-Go Task and the incompatible and compatible color-word stimuli during the Stroop Task. Mean reaction time and the SDRT were also calculated for the button press response to these Stroop stimuli. For the Go/No-Go Task, reaction times could only be summarized for "Go" stimulus trials.

Analysis Plan

A large number of dependent measures were collected for the purpose of comparing the background characteristics, task performance, and P300 responses of groups with a BMIP between 5 and 85 (lean; n=96) versus ≥ 95 (obese; n=92). The number of measures and analyses raised concerns about inflation of the Type 1 error rate. To allay the concern, the first step in the analysis plan was a simultaneous test of the Group effect across all measures via MANOVA. Univariate tests for group differences on individual dependent measures were performed if and only if the overall test was significant.

Another concern about the analysis comes from other studies showing that age is often correlated with task performance and brain activity. The groups did not differ significantly on age. However, controlling its effects in the analysis seemed appropriate and necessary. In the MANOVA and consequent ANOVAs, age was entered as a covariate.

The third concern about the analysis plan was a question about the value of analyzing P300 data separately by electrode site, because some studies of adults have found that frontal brain structure and function might have a stronger relationship with performance variability than brain structure or function measured in other regions. However, an initial examination of the data revealed no pattern in the P300 data justifying this sub-analysis. To improve the reliability of the parameter estimates, we reduced the number of measures by averaging the P300 means and standard deviations across the 3 electrode sites.

The fourth concern was specific to the Stroop Task. The design of the task yields 3 trial types: neutral, incompatible, and compatible color-word combinations. However, our hypotheses were focused on the difference between the latter two types, i.e., the Stroop effect. To simplify the analysis and reduce the number of tests, we computed reaction time and P300 differences between the two types and used these in the analysis.

The fifth concern was a question about the relationship of ISV in reaction time to ISV in P300 amplitude. The obvious solution to the concern was to compute a correlation coefficient between these variables across all subjects and separately for the tasks. Because the Obese and Lean groups were expected to differ on each variable, the distribution was not expected to be normal. Therefore, the non-parametric Spearman rank-order method was used.

The final concern was specific to the Go/No-Go Task. This task is a special case and problem because its rare, “No-Go” trials are trials on which the subject is instructed to suppress a response. On these trials, one can record a P300 ERP. However, one cannot also record a button press response unless it is executed erroneously, i.e., a false alarm. Therefore, one cannot directly relate the ISV of the No-Go P300 ERP to the ISV of the reaction time response on the same trial. As an alternative, we did compute a correlation between the No-Go trial P300 ISV and the Go trial reaction time ISV (i.e., SDRT). To validate the Go trial SDRT as an indicator of variability in response inhibition, we also calculated a Spearman rank-order correlation between it and the number of false alarm responses on No-Go trials. Several authors^{34, 51} have suggested that this alternative approach is valid.

RESULTS

The multivariate test for the effect of Body Mass Group on the complete set of dependent measures was statistically significant (Roy's Largest Root=1.93, $F(19,167)=17.07$, $p<0.001$). Further univariate tests were therefore justified. The findings from these analyses are reported below.

Background Characteristics

Table 1 presents age-adjusted means, standard errors, and effect sizes (Cohen's d^2) for the BIS, BSL, ICU, TAS, and DAST scales. Corresponding statistics are also reported for skinfold thickness averaged over the right and left triceps.

The analyses revealed significant group differences for four of the descriptors in the table. The Obese body mass group exhibited greater triceps skinfold thickness than the Lean body mass Group [$F(1,185)=269.1$, $p=0.001$]. The members of this group also reported higher scores on the DAST [$F(1,185)=4.6$, $p=0.033$], BSL [$F(1,185)=3.8$, $p=0.051$], and ICU Callousness [$F(1,185)=4.5$, $p=0.034$] scales. No other group differences were statistically significant.

Task Performance

The accuracy of subjects in performing the tasks was adequate to justify an analysis of their reaction times. During the Go/No-Go Task, the average accuracy was 89.9%. During the Stroop Task, average accuracy in the difficult, incompatible color-word condition was 83.0%.

An informal examination of the reaction time findings reveals a modest advantage in effect size associated with analyses of ISV versus the mean (see Table 1 and Figure 2). In the analysis of Go/No-Go data, statistically significant effects of Group were found for both the ISV of reaction time [$F(1,185)=10.4$, $p=0.001$] and mean reaction time [$F(1,185)=9.3$, $p=0.003$] with a modest difference in the associated p-values and effect sizes. Subjects with an obese body mass were more variable and slower in their responses during the task than peers with a lean body mass. They also executed more false alarm responses [$F(1,185)=9.1$, $p=0.003$].

The analysis of Stroop Task data revealed a similar pattern. However, the statistical effects of Group were not significant [SDRT: $F(1,185)=0.5$, $p=0.480$; mean reaction time: $F(1,185)=0.1$, $p=0.705$]. Table 2 and Figure 2 report the effect sizes.

P300 Event Related Potentials

Analyses of P300 ISV and mean amplitude revealed a pattern of results across tasks that corresponded to the pattern found in the analysis of reaction time. For the Go/No-Go Task, the ISV of P300 amplitude [$F(1,185)=6.8$, $p<0.010$] was modestly better than the mean [$F(1,185)=5.1$, $p=0.024$] for differentiating the groups. For the Stroop Task, the ISV was markedly superior [$F(1,185)=4.0$, $p=0.046$] to the mean [$F(1,185)=0.1$, $p=0.701$] in differentiating groups. It is important to recognize, however, that the direction of the group differences in ISV was opposite to what was found for reaction time: P300 amplitude was less variable over trials in the Obese group versus the Lean group.

Associations Among Variability Measures

To test a secondary hypothesis about the subject-by-subject association of P300 ISV with reaction time ISV, Spearman rank-order correlations were computed separately for Go/No-Go and Stroop task data. Across both tasks, lower trial-to-trial variability in P300 amplitude was associated with higher trial-to-trial variability in reaction time. For the Go/No-Go Task, the correlation was $r = -0.140$ ($p=0.066$). For the Stroop Task, the correlation was $r = -0.197$ ($p=0.006$).

A separate correlation was computed as a check on the validity of Go-trial SDRT during the Go/No-Go Task. This correlation of Go-trial SDRT with the number of false alarm responses on No-Go trials was statistically significant ($r = 0.193$, $p=0.007$).

DISCUSSION

This investigation focused on an atypically large sample of adolescent girls classified by their body mass index percentile. It revealed that the reaction times of girls with an obese body mass were more variable during the Go/No-Go task than those of their lean body mass peers. Accompanying the greater ISV in reaction times was a group difference in P300 amplitude ISV in the opposite direction for both the Go/NoGo and Stroop tasks. The effect sizes associated with these group differences in ISV were marginally greater than the effect sizes for the comparisons of the group means.

Readers are likely not surprised by the reaction time findings (Table 2) of this investigation. The extant literature demonstrates that the vast majority of obese adolescents do not have significant cognitive impairment¹. They are able to mobilize additional resources when needed and can maintain normal performance for most trials of a task. One could therefore intuit that a measure of stability in their reaction times, i.e., the mean, might not reflect their underlying information processing problems as well as a measure of trial-by-trial instability in reaction time, i.e., its ISV.

One could also intuit that obese adolescents would show greater ISV in reaction time relative to their lean body mass peers. Enhanced ISV in reaction time has previously been reported in obese adolescents^{5, 22, 23}. It has also been reported in studies of adolescent or adult subjects with disorders, such as ADHD⁵³ and Borderline Personality Disorder⁵⁴, which are associated with an elevated prevalence⁵⁵⁻⁵⁷ of obesity.

Many factors⁵⁸ can be envisioned that may account for elevated ISV in reaction time in the obese group. One possibility is learning which would be indicated by a peak in performance variability at task onset. The peak may be followed by a decrease in variability over time as the subject searches for, and later finds, an optimal strategy.

Other possibilities involve changes in attentional focus²⁵ that are either voluntary or involuntary. An example may be episodes of instability that arise as the obese subject experiments with different strategies on different trials to compensate for the monotony of the task. Alternatively, one may see bursts of reaction time variability when brief lapses in attention trigger a change in response bias or the activation thresholds for different task solution strategies.

Intuition might not have pointed readers toward an accurate prediction of our P300 findings (Table 2). Logic may have predicted a different outcome--an elevation in P300 ISV in the obese group that parallels the elevation in the SDRT. This prediction is consistent with the view that ISV in P300 amplitude is a simple reflection of noise resulting from inefficiencies in neurotransmission which are then reflected in the motor output. However, several authors^{59, 60} have argued that neural systems can show a counterintuitive property wherein greater variability in neural processing indicates an optimum or healthier state. From this

state, transitions in signal processing can be more facile and more networks can be engaged in service of optimizing and reducing the variability of the behavioral output. In this context, our demonstration of less ISV in P300 amplitude among obese versus lean adolescent girls suggests a diminution in the former group in their dynamic range or functional plasticity. Our demonstration of a significant negative correlation between ISV in P300 and ISV in reaction time, within subjects and across two tests of response control, is consistent with this counterintuitive explanation.

The diminished ISV in P300 and enhanced ISV in reaction time found by us among obese adolescent girls may be informed by findings from another literature. In a study of normal brain maturation from adolescence to young adulthood, McIntosh and colleagues³⁵ showed less brain signal variability, suggestive of less neural complexity, in the immature brains of the adolescents. In the relatively mature brain of the young adults, they showed increased variability in brain activity with an accompanying decrease in reaction time variability. Our findings in obese adolescents might therefore be interpreted as evidence of a less mature central nervous system. We do not know if this immature state will resolve over time. It may persist into adulthood, constrain brain function, and continue to influence response inhibition and cognitive control. We also do not know if the decrement in neural complexity is relevant to specific cognitive skills supportive of successful weight control, including accurate judgements of portion size⁶, and attending to and recalling complex information⁵ about diet and calorie restrictions. A prospective study may provide an answer to these questions. It would also be valuable in a future study to explore these questions in a more diverse sample that includes males as well as subjects from other cultural backgrounds. From the data available presently, we cannot determine if the individual and group differences in ISV are stable over time or sample specific.

Summary and Conclusions

The principal goal of this investigation was to demonstrate that intra-subject variability is at least as valuable as the intra-subject mean in differentiating groups of adolescent girls with an obese versus lean body mass. The goal was met. Across two tasks wherein reaction time and brain activity were measured, the effect sizes associated with the variabilities of these indices were consistently superior to the effect sizes associated with their means (Figure 2).

The superiority of ISV as an index of group differences argues for its use in future studies, especially when the differences are expected to be subtle. It also invites a consideration of sources of ISV that may differ across individuals within a group. In future studies, investigators may wish to explore the relative contributions of habituation or learning, attentional lapses, and fatigue to variability in brain function and behavior.

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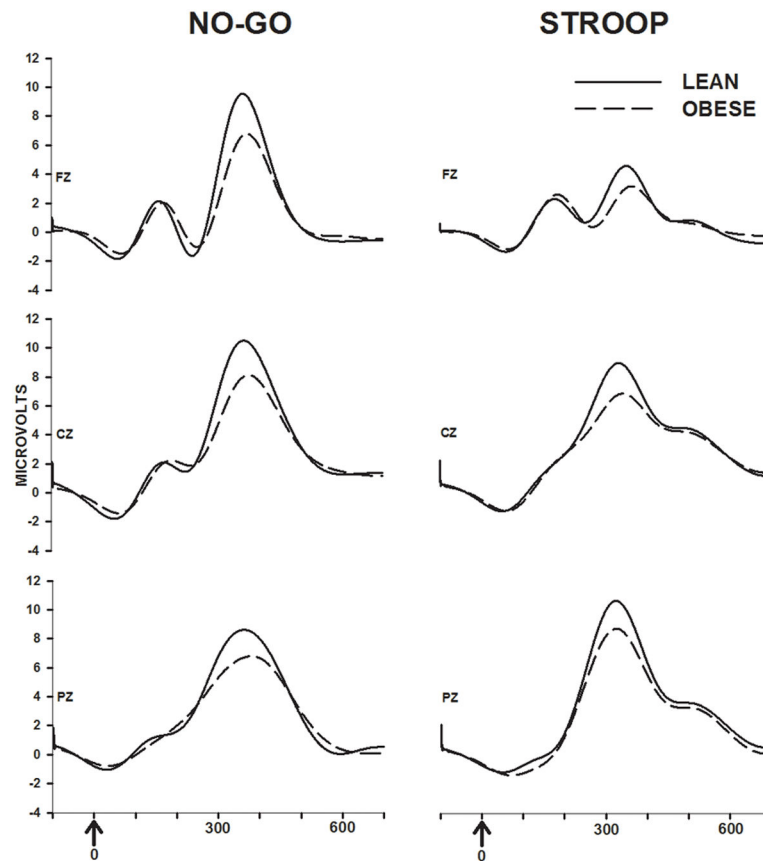


Figure 1.

Group-averaged event related potential waveforms measured at 3 scalp sites (Fz, Cz, Pz) around the onset of the No-Go and incompatible color-word stimuli during the Go/No-Go (left) and Stroop (right) tasks. Note the decrement in P300 amplitude in the obese group. The time scale is -100 to +700 ms relative to stimulus onset.

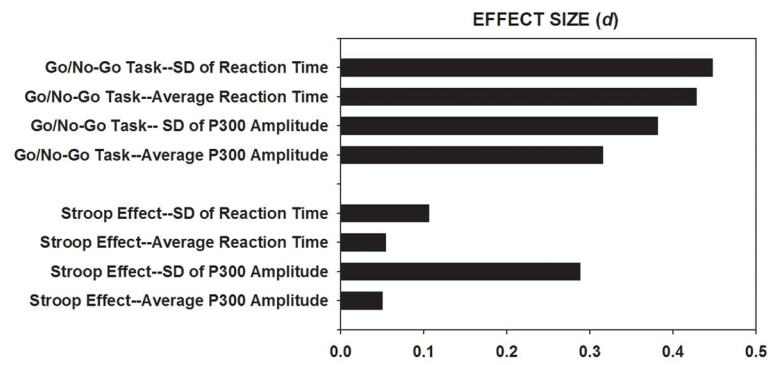


Figure 2.

Effect sizes (Cohen's d) for tests of group differences. Note that larger effect sizes accompany tests of intrasubject variability across both tasks and for both reaction time and P300 amplitude.

Table 1

Background characteristics sorted by group.

	Lean Body Mass N=96	Obese Body Mass N=92	Cohen's d^{\dagger}
Average Tricep Skinfold Thickness in mm (SE)	24.9 (0.7) *	42.8(0.7) *	2.37
Age in months	191.9(1.6)	191.7(1.5)	0.01
BIS [‡] Total Score	61.0(1.0)	61.9(1.0)	0.08
BSL [§] Total Score	9.7(1.3) *	13.4(1.3) *	0.28
ICU// Callousness Score	5.6(0.3) *	6.8(0.3) *	0.31
ICU// Uncaring Score	6.8(0.2)	6.9(0.3)	0.05
ICU// Unemotional Score	6.1(0.4)	6.5(0.4)	0.12
DAST [¶] Total Score	0.4(0.1) *	0.7(0.1) *	0.32
TAS [#] Ability to Describe Feelings	13.3(0.3)	13.3(0.2)	0.01
TAS [#] Ability to Identify Emotions	17.7(0.4)	17.1(0.4)	0.15
TAS [#] Externally Oriented Thinking	23.4(0.3)	23.8(0.3)	0.13

*
p<0.05.[†] Cohen's d is an effect size estimate. It is computed as the difference in group means divided by the pooled standard deviation. Values of 0.2, 0.5, and 0.8 are respectively described as small, medium, and large effects.[‡] BIS, Barratt Impulsiveness Scale. The range of possible scores is 30–120.[§] BSL, Borderline Symptom List. Score range=0–92.

// ICU, Inventory of Callous-Unemotional Traits. For the Callousness, Uncaring, and Unemotional subscales, the respective score ranges are 0–33, 0–24, and 0–15.

[¶] DAST, Drug Abuse Screening Test. Score range=0–10.[#] TAS, Toronto Alexithymia Scale. For the Describing Feelings, Identifying Feelings, and Externally Oriented Thinking subscales, the respective score ranges are 5–25, 7–35, and 8–40.

Table 2

Performance and P300 Data by group.

	Lean Body Mass	Obese Body Mass	P =	Cohen's <i>d</i>
Go/No-Go Task Data (SE)				
SD of Reaction time	86.9(4.4) *	107.6(4.5) *	0.001	0.44
Mean Reaction Time in ms	247.3(6.0) *	273.6(6.1) *	0.003	0.42
False Alarms (proportion of trials)	0.18(0.01) *	0.24(0.01) *	0.003	0.42
SD of P300 Amplitude	10.8(0.1) *	10.1(0.1) *	0.010	0.38
P300 Amplitude Mean	4.5(0.3) *	3.7(0.3) *	0.024	0.31
Stroop Task Data (SE)				
Difference [†] in SD of Reaction Time	23.7(3.9)	19.7(3.9)	0.480	0.11
Difference [†] in Mean Reaction Time	24.4(4.0)	26.6(4.1)	0.705	0.05
Difference [†] in SD of P300 Amplitude	0.23(0.1) *	-0.26(0.2) *	0.046	0.28
Difference [†] in Mean P300 Amplitude	-0.65(0.3)	-0.49(0.3)	0.701	0.05

* P<0.05

[†] Incompatible Minus Compatible Trial Difference